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PRELIMINARY RESULTS WITH THE BORAX TREATMENT OF CITRUS FRUITS FOR THE PREVENTION OF BLUE MOLD ROT[1]

By HARRY R. FULTON, *Pathologist, and* JOHN J. BOWMAN, *Junior Pathologist, Office of Fruit Disease Investigations, Bureau of Plant Industry, United States Department of Agriculture*

Recent studies by the senior author on the effect of ultraviolet light in disinfecting the surface of citrus fruits, details of which will be published in the near future, have indicated that more than 99 per cent of blue-mold spores may be killed very quickly by light of short wave lengths, and at comparatively low cost, but that blue-mold rot is not proportionately checked. The two weak points in the ultraviolet treatment seem to be (1) the difficulty in killing the last small percentage of Penicillium spores, and (2) the lack of any later protection against stray spores that remain unkilled or may reach the fruit. Being thus strongly impressed with the desirability of using some agent that would have a continuing effect, the writers have undertaken the testing of a large number of mild chemical reagents with a view to finding inhibiting rather than killing substances. The stronger disinfectants would be objectionable, because their poisonous character would not permit residues to be left and because many of them would actually injure the surface of the fruit if not immediately washed off.

The general procedure has been to select chemicals for preliminary tests largely on the basis of cheapness and availability. Spores of Penicillium were treated with relatively strong solutions of these chemicals for periods of 1 to 24 hours, and were then plated to determine the killing effect. Parallel tests were made for inhibition. Any reagent that seemed at all promising was then applied to a few citrus fruits to determine whether it would injure the skin. If it seemed safe to use, an actual test was made to determine its protective action on severely wounded and inoculated fruit held under conditions of temperature and moisture favorable for blue-mold development. Usually some one of the stronger fungicides was included in each test as a basis for comparison.

Holding tests have been made thus far with fruit treated with solutions of the following chemicals: Sodium sulphate, sodium bisulphite, sodium borate, sodium fluoride, sodium perborate, sodium chloride, potassium permanganate, potassium borate, copper borate, bichloride of mercury, boric acid, salicylic acid, benzoic acid. Among these sodium borate, or borax, has seemed to give best protection against blue-mold rot.

The results of one holding test, made March 14, 1924, which included borax along with certain other materials will serve as an illustration and is shown in Figure 1. California navel oranges purchased in the Washington, D. C., market were used. The fruit was soaked for 10 minutes in inoculum carrying about 500,000 per cc. of mixed *Penicillium digitatum* and *P. italicum* spores. The fruits were dried, then atomized with the chemical solution (the control with water); dried again; punctured 100 times with pins to a depth of about half way through the peel. They were wrapped in waxed paper, packed in a tight

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barrel with wet newspaper between each two layers of fruit; and were kept at room temperature of about 72° F. Examination for rot was made every three days. The results show some benefit from all of the chemicals; 1:5000 bichloride of mercury, 5 per cent boric acid, and 5 per cent sodium bisulphite had approximately the same effect; and 5 per cent sodium borate (borax) was distinctly

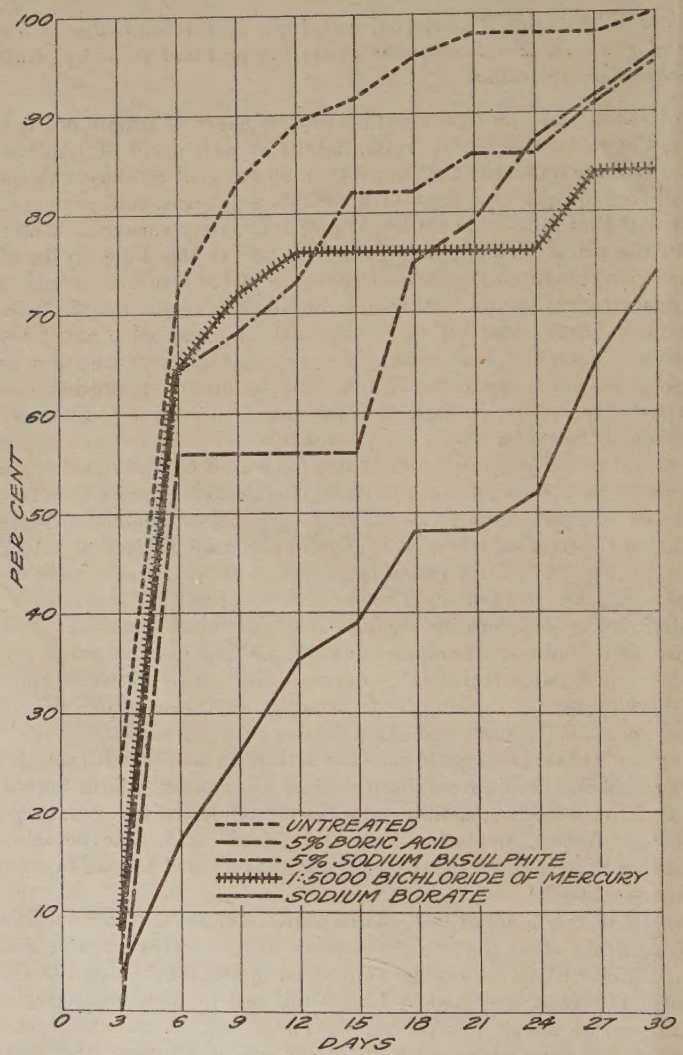

FIG. 1.—Percentages of blue-mold rot developing in oranges treated with various chemicals and those untreated during 30 days

more effective, particularly during the first 24 days of the test. In Figure 2 are shown the average results of 15 tests on oranges of 5 per cent borax treatment, as compared with no treatment, and 5 tests on lemons. These tests were made at various times. In all cases the fruit was punctured at 100 points, was inoculated with a suspension of blue-mold spores, and was packed between wet paper. The strength of the inoculum was varied in some of the tests, as was the sequence

of puncturing, inoculating, and treating with borax. The method of applying the 5 per cent borax solution was either by dipping the fruit momentarily in the solution, or by soaking for 1 minute or for 10 minutes, or by atomizing over the fruit, or by applying with a brush; all of these methods proved effective. The averages are based on 491 treated and an equal number of untreated fruit for

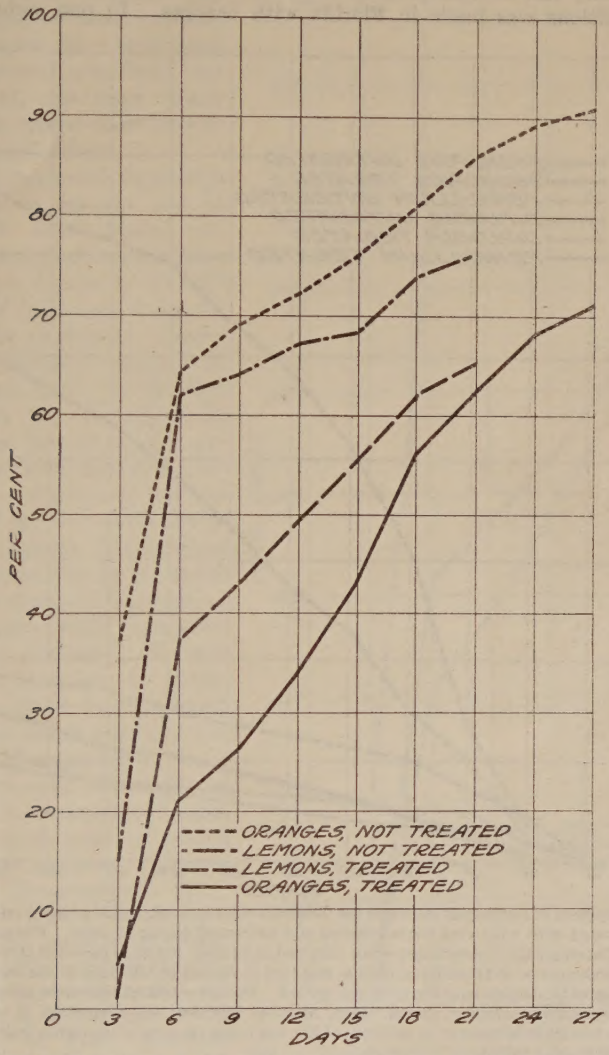

FIG. 2.—Percentages of blue-mold rot developing in oranges and in lemons treated with 5 per cent borax solution and untreated during 27 and 21 days

the oranges, and on 270 fruits for the lemons. They show the effectiveness of the treatment under conditions of infection far more severe than would occur in even the worst commercial practice. The treatment with 5 per cent borax solution resulted under these exceedingly severe conditions in a distinct reduction in blue-mold rot, but did not give what would be considered satisfactory control. The treatment seemed to be more effective on oranges than on lemons.

In certain other tests the fruit was not only punctured, but was severely bruised by dropping several times from a table to the floor, and several slices resembling very severe clipper cuts were cut from the outside of the peel. In such cases soaking one minute in 5 per cent borax solution had a very satisfactory protective effect, but the mere brushing on of the solution was less effective.

A preliminary test to determine the value of the borax treatment under commercial conditions was made in Florida with oranges. In one series of tests

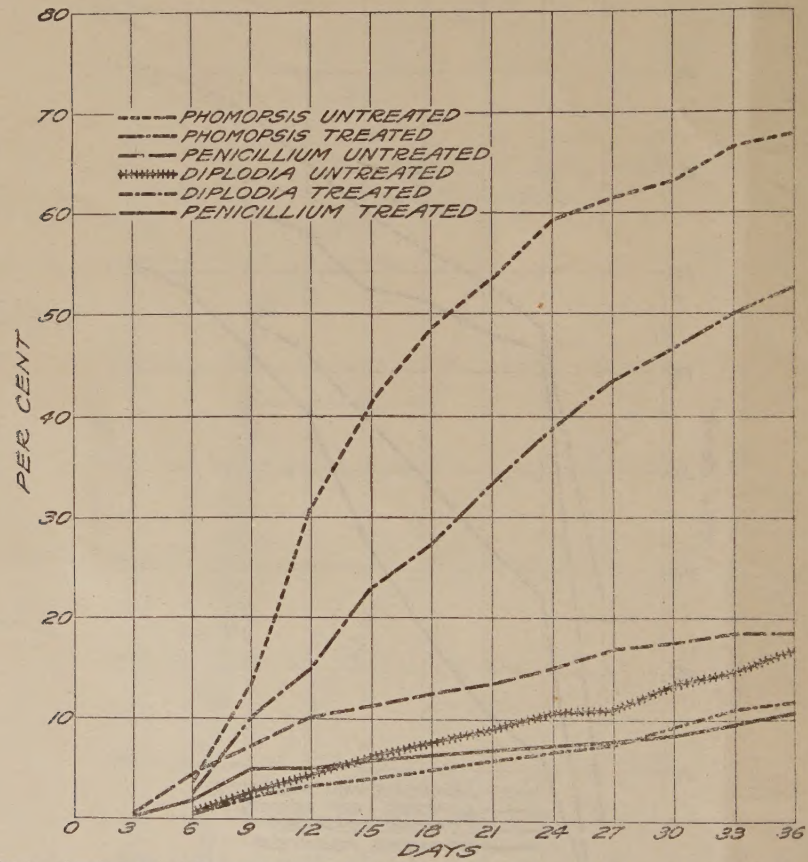

FIG. 3.—Development of Phomopsis stem-end rot, Diplodia stem-end rot, and blue mold rot (Penicillium) in oranges treated with 5 per cent borax solution and untreated during 36 days. The numbers at the left indicate the cumulative percentages of rot obtained as follows: For each period of three days the percentage of Phomopsis or of Diplodia or of blue mold rot is figured on the basis of the number of sound fruits in the test at the beginning of the three-day period. These percentage figures are added successively to give the cumulative numbers shown. Such numbers represent the proportion of rot that would develop if the test lot were restored to 100 fruits of like kind after removal of the rotten fruits at the beginning of each three-day period

samples of 100 fruit were taken from the packing houses; each sample was divided into two lots, one lot was dipped momentarily through 5 per cent borax solution and the control lot through water; the fruit was allowed to dry, and was held for several weeks at approximately 74° F. in a rather moist atmosphere. These conditions of temperature and moisture are more favorable for rot than usual commercial conditions, but were considered desirable in order to induce enough rot for a definite showing. In Figure 3 the averages are given for 11 sample lots of 50 oranges each, representative of Florida oranges in late April,

including Valencias in their prime and seedling oranges that were dead ripe. There is a distinct reduction in all three rots, Phomopsis and Diplodia stem-end rots showing decided reduction as well as blue-mold rot. This reduction in stem-end rots was an entirely unexpected outcome of the experiment. One possibility is that the borax solution may penetrate and disinfect the calyx edges or other portions of the button in which these two stem-end rot fungi are established, and from which they later extend their growth into the stored fruit.

Two commercial shipments of boxes of oranges and of grapefruit were made, one during April and one in May, 1924, from points in Florida in regular fruit cars under refrigeration to Seattle, Wash., and by ordinary express to Washingon, D. C. Not enough blue-mold rot developed in either the treated or the untreated fruit for definite showing, even during a holding period of several weeks duration after arrival. The boraxed fruit in these shipments again showed a distinct reduction of stem-end rot when compared with the controls. Further tests will be made to determine the effect on blue-mold rot of the borax treatment in commercial shipments.

The question arose as to whether increasing the strength of the borax solution would give better control. At ordinary air temperature water saturation occurs at about 6 per cent or 7 per cent of borax but solubility increases rapidly with rise in temperature. At 85° F. it is approximately 7 per cent; at 113°, approximately 14 per cent; and at 122°, approximately 18.5 per cent. In California lemons and oranges are usually washed for several minutes in water between 115° and 120° for control of brown rot without bad effect. In the warm-water tests the writers have used 10 per cent commercial borax in water maintained at 122°, on plump but not turgid fruit that had been off the trees at least 10 days when purchased from the market. Seven tests, two with oranges and five with lemons, are averaged in figure 4. The percentages of rot are based on

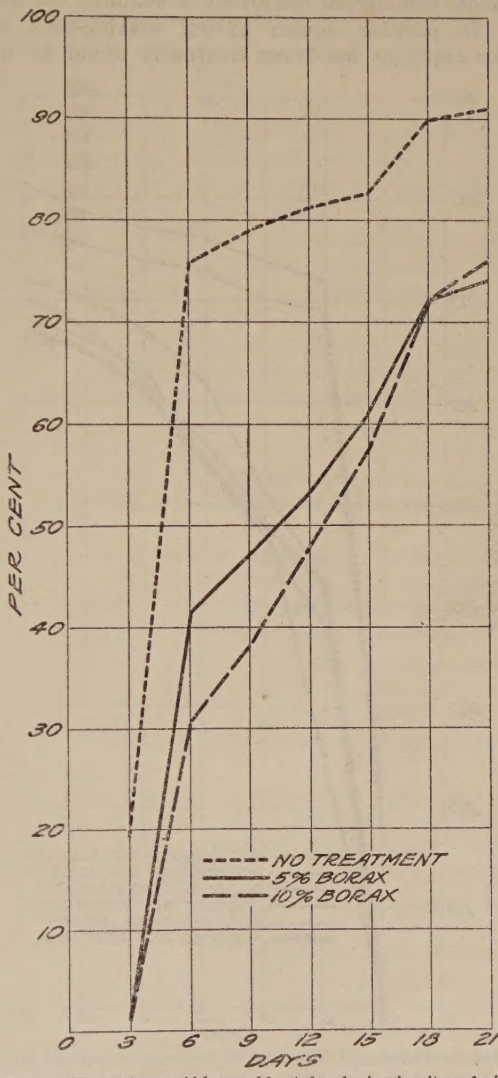

FIG. 4.—Percentages of blue-mold rot developing in citrus fruit treated with 5 per cent and with 10 per cent borax solution and untreated during 21 days

275 fruit originally given each treatment. There is some difference in favor of the 10 per cent as compared with the 5 per cent borax dipping treatment. It is possible that soaking tests of several minutes in the warm solution would show an increased effectiveness. The question requires further testing under commercial conditions of handling the fruit.

In packing houses having soaking-tank equipment a convenient place for applying the borax treatment would be in this tank. Usually the fruit passes from the soaking tank to scrubbing brushes over which streams of water play. These would wash off most or all of the borax. In the absence of a soaking tank, or for the purpose of leaving as much as possible to dry on the fruit surface, the borax solution might be played over the scrubbing brushes in small streams from perforated pipes leading from overhead tanks, or some atomizing device might be used just before the fruit enters the drier. Where polishing brushes are used after the fruit has dried, much of the borax coating would be removed. Tests were made to determine whether the removal of the borax coating, either by washing the freshly treated fruit or by brushing those on which the borax had dried, would materially lessen the protective effect. The fruit was heavily inoculated and was packed away between layers of moist paper at room temperature. Figure 5 shows the average results of seven separate tests, five with lemons, and two with oranges, totaling 340 fruits. The strength of the borax solution was 5 per cent for five of the tests and 10 per cent for two.

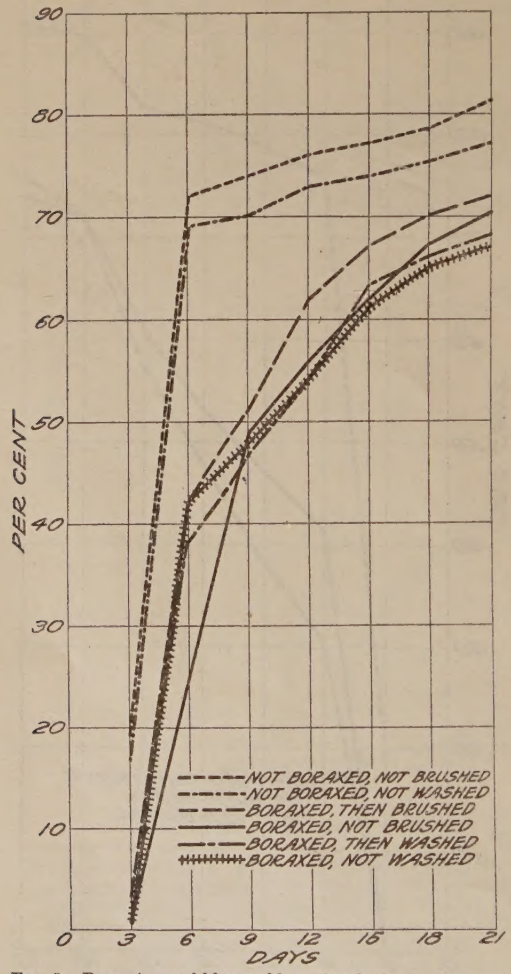

FIG. 5.—Percentages of blue-mold rot developing in citrus fruit treated with borax solution (two tests), treated with borax solution and later washed, treated with borax solution and later brushed, and untreated (two tests) during 21 days

These results indicate that removal of the coating of borax really makes little difference. This is at variance with the working hypothesis on the basis of which this work was undertaken. It may be that borax penetrates to some extent the tissues, especially at wounds, and thus has a residual effect even though the surface crystals are not present in quantity. However, one would naturally suppose that a surface coating of small crystals of an antiseptic substance that would readily dissolve in any moisture that would allow spore germination would give

added effectiveness in preventing such germination or subsequent invasion by the fungus mycelium. After the brushing the deposit of borax crystals remained, or was even increased in depressions, but was removed from the high places.

Practical packing-house tests will be required to determine the most effective and economical way of applying the borax treatment. From these preliminary laboratory tests it seems that the treatment would be about equally effective in any one of the several methods of application discussed.

Tests were made on the effectiveness of borax treatments at various intervals after artificial inoculation. The best results were obtained when the treatments followed immediately. With the lapse of two and one-half hours the treated fruit was no better than the untreated control. On the other hand, the tests with "commercially sound" fruit taken from packing houses, frequently one or two days after picking, indicate a material reduction in blue-mold rot and in stem-end rot, as is shown in figure 3. It is important to avoid delay in treating the fruit, and the borax treatment must not be relied upon to make up for careless handling. All the tests with severely wounded fruit indicate that the borax treatment will by no means prevent all of the rot. In general the laboratory tests had the advantage over carelessly handled commercial fruit of receiving the treatment promptly after wounding and had the disadvantage of being subjected to exceedingly severe wounding and holding conditions. The borax treatment should be regarded as a supplement to and not as a substitute for careful handling. It gives promise of having a place in protecting the fruit against a considerable proportion of the blue-mold rot that is likely to occur even with very careful handling, especially that incident during and after the packing process.

Borax has the advantage of being cheap and readily obtainable. It does not actively corrode metal and is not a poison. It is an article of common household use. The coating, even when freshly made with 10 per cent solution, is not very conspicuous on oranges and lemons; on grapefruit it shows at first somewhat more prominently as a grayish coating. After the fruit has been wrapped and packed and held for a week or more, one must look very closely to detect any difference in appearance between the treated and untreated fruit. It does not seem probable that the borax coating, even if all is left on the fruit, will detract materially from its appearance or affect its marketability.

As is well known, regulations of the United States Department of Agriculture, made under the pure foods act, prohibit the use of borax or certain other preservatives in food products and restrict their use on the surface of such products. In the case of citrus fruits the application of borax is made to the outside of the peel, a portion of the fruit that is not regarded as edible and that is discarded in the ordinary consumption of the fruit. If the fruit is washed before using, the adhering borax is readily removed. In commercial establishments for extracting juice and for manufacture of citrus by-products the general practice is to wash the fruit before using. In the making of citrus drinks the fruit is doubtless used sometimes without washing and the peel put in the drink. In this case there is considerable dilution with liquid. Our tests show that an orange of medium size, on an average, will remove 1 cc. of 5 per cent borax solution when dipped. Perhaps half of this drains off. On this basis a single orange might carry 0.025 gram (0.4 grain) dried borax on its surface. The therapeutic dose is given as 0.750 gram (12 grains), and is the equivalent of what might be carried on about 30 oranges.

Chemical analyses are being made by the Office of Soil Fertility Investigations of this bureau to determine the amount of borax present on and in the peel and in the edible pulp portion of oranges and of lemons that had been held 15 days

after treatment with borax solution of 5 per cent and of 10 per cent strength. Preliminary results indicate that the amounts present are even much smaller than those indicated and that the borax does not penetrate to the edible portion of the fruit.

No injury to the fruit through the use of borax solution has been observed. Most of the tests were made with fruit obtained on the market some time after picking, but a number of tests on grapefruit and on oranges were made with freshly picked fruit. The effect on very turgid fruit has not been fully tested.

SUMMARY

Preliminary tests have shown that commercial borax (sodium borate) solution in strength of 5 per cent or 10 per cent applied to the surface of oranges or lemons and allowed to dry greatly reduces blue-mold rot under experimental conditions that are unusually favorable for rot development.

Oranges and grapefruit handled in a commercial way, when treated with the borax solution, showed a marked reduction of both Phomopsis and Diplodia types of stem-end rot, as well as of blue-mold rot.

The borax treatment gives promise of being commercially valuable, in conjunction with careful handling of the fruit, in reducing losses from blue-mold rot.